ANNUAL REPORT FY2013
Habitat Assessment Funded Research

Project Title: Incorporating environmental and habitat characteristics into the brown shrimp stock assessment for the northern Gulf of Mexico

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Goals: Our goal is to create a compartment-based systems model that incorporates factors affecting brown shrimp growth and mortality. The finished model will be user-friendly, cost-effective, and flexible. The driving variables for the model include temperature, salinity, and access to emergent marsh habitat, and the output of our model can be incorporated into the Stock Synthesis 3 model recently developed for brown shrimp in the Gulf of Mexico. The overall objective is to reduce habitat-related uncertainty in the brown shrimp stock-recruit relationship.

Approach: Several models have been developed to describe the relationships between shrimp growth and water temperature, salinity, and tidal flooding of emergent marsh vegetation. This project incorporates data from correlative models (Barrett and Gillespie 1973, Turner 1992, Haas et al. 2001), Individual Based Models (Haas et al. 2004, Roth et al. 2008), a bioenergetics model (Adamack et al. 2012), and a spatial density model (Minello et al. 2008) into a compartment based systems model that will predict the annual influence of environmental conditions on juvenile brown shrimp production in GoM estuaries. In our model, production is influenced (through growth and mortality) by temperature, salinity, and access to emergent marsh vegetation. We are using Stella® 9.1.4 (iSEE Systems, Incorporated, Lebanon, New Hampshire, USA) and NetLogo (Wilensky 1999) modeling software; these packages are relatively inexpensive, are readily available, and require short processing times on a single desktop computer.

Brief Summary of How Funds Were Used: The majority of funding was used to support Jennifer Leo (Ph.D. student at Texas A&M) and the contract staff that assisted with field collections and sorting samples in the lab. Funds also went towards field collection supplies.

Work Completed: In Year 1 of the project (FY2011), we initiated model development with Bill Grant of Texas A&M University. We completed field studies designed to measure growth of brown shrimp in marsh ponds in relation to the driving variables in the model. The results from this work will be used to test or corroborate initial model results.

In Year 2 of the Project (FY2012), we completed a field growth study that compared brown shrimp growth between three habitat types: *Spartina* marsh, seagrass, and non-vegetated bottom. Shrimp were marked with visible implant elastomer tags and placed in 0.89 m-diameter mesh cages (45 cages total) at three treatment levels: Five shrimp, ten shrimp, or ten shrimp with food added to the cage daily. We collected benthic cores to assess potential prey availability at each cage site. Growth data were analyzed, and we are processing the benthic core samples.

A large portion of the modeling also has been completed in Year 2. We have created processes within the model which account for the effects of temperature, shrimp size, habitat, and flooding regime on growth and mortality of juveniles at an hourly time step. We have proposed to run the model in both Galveston Bay, TX and Barataria Bay, LA as representative systems in the northwestern Gulf of Mexico. An important requirement for the utility of model runs, therefore, is the development of long-term time series data on shrimp abundance, estuarine salinity patterns, flooding durations of marsh vegetation, and water temperatures in the marsh.

Historical trawl catches for both bays will be used to estimate annual variability in shrimp abundance. Monthly salinities in Galveston Bay have been modeled from 1977 to 2005 by the Texas Water Development Board (TxBLEND), and these data can be used to determine the proportional area of the bay at different salinities each month. Comparable data are not available for Barataria Bay, and we are in the process of krieging available point data to develop similar information.

Flooding of marsh edge habitat controls access to the marsh surface, an important habitat being modeled, and we measured marsh edge elevations and flooding durations from tide gauge data in both Galveston Bay and Barataria Bay in 2008. Estimating long-term trends in marsh flooding, however, requires an adjustment for relative sea level rise (SLR) on tide gauges; at the Grand Isle gauge at the mouth of Barataria Bay for example, relative SLR was 0.64 cm year^{-1} from 1981 to 2011. If we assume that the marsh edge sinks at the same rate as the tide gauge and that *Spartina alterniflora* located at the marsh edge is at its limit and cannot withstand additional submergence, the elevation of the marsh edge from historical gauge records can be predicted based on relative SLR. As mean water levels rise on the gauge over time, the location of the marsh edge in relation to the gauge will rise accordingly. Using this approach to de-trend the tide gauge records for 1981-2011 at Grand Isle, we estimate that annual flooding of the nearby Barataria Bay marsh edge ranged between 61.1% in 1988 to 79.8% in 1983.

Juvenile shrimp are concentrated in the shallow water near the marsh edge, and water temperatures here can be substantially different from those in the open bay. Our brown shrimp model runs on an hourly time step, and we developed a submodel to estimate hourly temperatures in both shallow open water and flooded vegetation based on median daily air temperature, available for Galveston Island from 1946 to 2012 (NOAA Weather Service). From March 16, 2006 through May 31, 2007, we used HOBO sensors (Onset Computer Corporation) to record hourly bottom water temperatures at a distance of 5 m from the vegetated marsh edge (open water habitat) and at 1 m within the marsh vegetation (marsh habitat). Median daily air temperature was used to predict mean daily water temperature in the open water habitat. For each month of the year, we then calculated the mean hourly deviation from the daily mean and used these data to estimate hourly water temperatures in shallow open water and on the marsh surface. The submodel estimates of hourly water temperatures based on daily median air temperature were closely related to actual water temperature measurements over the 1-year period with an R^2 of 0.91 for open water (Figure 1) and 0.88 for marsh.

The new brown shrimp Stock Synthesis 3 assessment model has been completed and run with commercial brown shrimp data from state and federal waters over the period 1984-2011 (Hart 2012). The model is parameterized with non-time varying selectivity and R_0 and an estimated steepness value. In the full time series model runs, fits to the CPUE estimates, size selectivity, spawning biomass, numbers of recruits, and fishing mortality estimates (F) were generated. This new modeling framework is capable of integrating the environmental and habitat related growth and mortality indices being modeled for marshes in Texas and Louisiana.

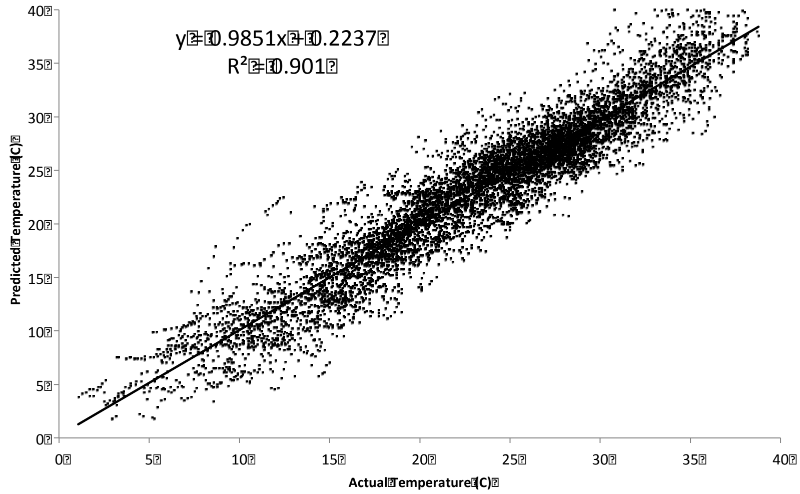

Figure 1. Relationship between the modeled (predicted) water temperature in shallow open water of a Galveston Bay salt marsh and the actual hourly temperature measured between March 16, 2006 and May 31, 2007.

In Year 3 of the project (FY2013), the modeling work continued while we completed several projects required to support this overall program. Using our GIS background, we combined the salinity model output from TxBLEND with the 2006 National Wetland Inventory (NWI) habitat cover for Galveston Bay to provide the required information on monthly salinity patterns in relation to different areas of emergent wetlands. Because older NWI maps were course in scale and did not identify much of the interspersed water present in wetlands, we checked the newer maps in relation to our previous analysis of 1995 DOQQ photographs (Minello et al. 2008) and more recent 2006 imagery for selected marsh areas in the bay, and we believe that the updated NWI maps adequately represent the amount of edge and interspersed water in the emergent wetlands of the bay. We now have the spatial framework for the model runs each month in Galveston Bay. There are nine habitat cells in model for salinities of 0-10, 10-20, and >20 psu and either marsh vegetation, shallow water associated with the marsh, or shallow water in the open bay.

The total number of postlarval brown shrimp entering the bay each year will likely affect production, and the impact of this annual variability will be examined through simulation exercises. But the seasonal variability of these recruits at a daily time step is required as a model input. We developed an approach to estimate this seasonal variability by analyzing 11 years of monthly brown shrimp density data from a marsh system in Galveston Bay (Rozas et al. 2007). We used the length-frequency data from these samples to identify the density of new recruits and used an estimate of growth (based on the monthly temperature) and daily mortality (from catch curve analyses) to back calculate the density of recruits for 1-2 weeks before the samples were collected. This analysis provides an average estimate of daily recruitment intensity over the year (Figure 2). This seasonal pattern with peak recruitment in the spring compares well with the pattern of postlarval recruitment through the pass into the bay.

Model validation requires time series data of brown shrimp abundance or production from Gulf of Mexico estuaries, and we have worked to develop these data based on resource trawl surveys conducted by states. We have published an assessment of the abundance, length frequency, and biomass of brown shrimp in 24 GoM estuaries over the years from 1986-2005 (Brown et al. 2013), and these data will be used for model validation. We also are working to develop a similar analysis identifying the areal coverage of different habitat types in these estuaries.

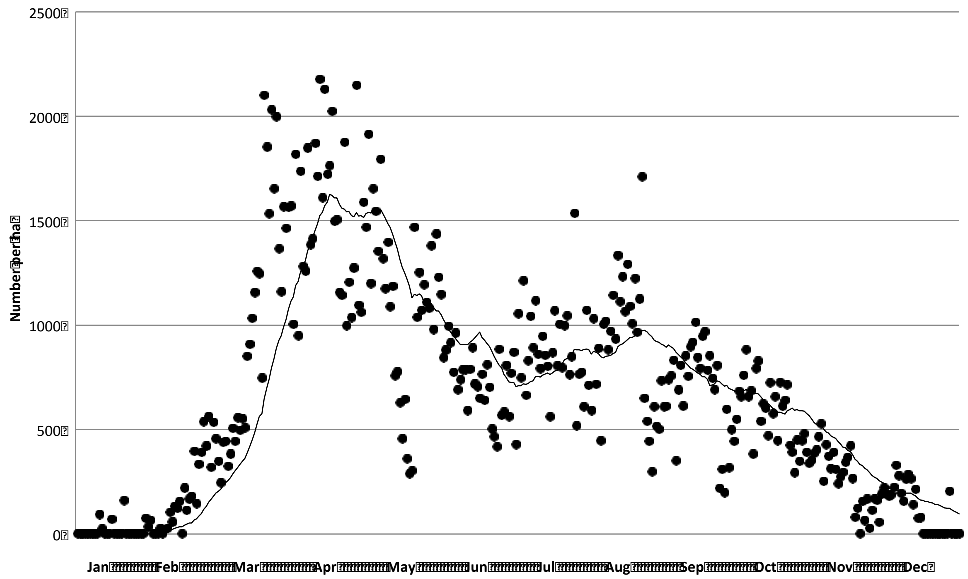

Figure 2. Simulated seasonal recruitment pattern of postlarval brown shrimp into salt marshes of Galveston Bay. Points are estimates of the number of 12-mm TL shrimp entering 1-ha of marsh complex, and the line is a 28-d moving average.

Variability in brown shrimp production in our model is based in part on marsh flooding patterns and on several lines of evidence indicating that growth varies in relation to the availability of flooded vegetation. We conducted a laboratory mesocosm experiment to check this basic model assumption. In April 2013, we collected young brown shrimp from Galveston Bay along with 70 large benthic cores (20.3 cm diameter, 0.032 m^2 area) along a 1000 m transect of marsh edge. We collected 35 cores within vegetation and 35 on nonvegetated bottom within 5 m on either side of the vegetation-open water interface. We used PVC cylinders to extract the cores; these cylinders had 0.5-mm mesh-covered windows placed just above the level of the sediment. These cylinders were transported to laboratory tanks where they served as shrimp growth mesocosms. In the laboratory, we used a manifold system to divert oxygenated recirculating water to each mesocosm. Shrimp were tagged with visible implant elastomer, and growth was measured over a 6 day period. Sediment samples also were collected before and after the experiment to measure the abundance of benthic infauna used as food by brown shrimp.

In accordance with the NMFS Data Documentation Directive, metadata for our collected and produced data have been entered and published in the NMFS Data Catalog and Metadata Repository, InPort (https://inport.nmfs.noaa.gov/). The catalog identification number for the project level metadata is 16983 and is published on the InPort website at https://inport.nmfs.noaa.gov/inport/item/16983 with additional data-set level metadata at https://inport.nmfs.noaa.gov/inport/item/16990.

Applications: On a smaller scale our model on the production of brown shrimp can be used to examine the effects of sea level rise, habitat loss or creation, freshwater diversions, or contaminants such as oil. With respect to fishery management, the output of our model can be incorporated into the recently developed Stock Synthesis 3 model, and is expected to help reduce habitat-related uncertainty in the brown shrimp stock-recruit relationship.

Presentations:

- Leo, JP, TJ Minello, WE Grant, R Hart, and J Nance (November 8-9, 2012) Relating habitat characteristics and quality to production of brown shrimp (*Farfantepenaeus aztecus*) in the northern Gulf of Mexico. Gulf Estuarine Research Society Meeting, Dauphin Island Sea Lab, Dauphin Island, Alabama
- Leo, JP, TJ Minello, R Hart, J Nance, and WE Grant. (September 5-7, 2012) Incorporating environmental and habitat characteristics into the brown shrimp (*Farfantepenaeus aztecus*) stock assessment for the northern Gulf of Mexico. National Habitat Assessment Workshop: Fisheries Science to Support NOAA's Habitat Blueprint, Montlake Lab, Seattle,
- Leo, JP, TJ Minello, WE Grant (February 9-11, 2012) Quantifying the effects of temperature, salinity, and marsh access on the growth of brown shrimp (*Farfantepenaeus aztecus*) in salt marsh ponds of Galveston Bay, Texas. Texas Chapter of the American Fisheries Society Meeting, Galveston Island, Texas

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